

XXVII. *Some farther Considerations on the Influence of the Vegetable Kingdom on the Animal Creation.* By John Ingen-houfz, Counsellor to the Court, and Body Physician to the Emperor, F. R. S. &c.

Read June 13, 1782.

UPON being informed, a few months ago, as well by private letters as from the Critical Review, that my doctrine was quite over-turned by the fifth volume of Dr. PRIESTLEY, and by an experiment quoted in the book of Mr. CAVALLO on Air; I invited some of my friends here to assist at some decisive experiments, of which I will here give an exact account. I told them the whole result which was to be expected from them, if my system was founded on nature, explaining to them before-hand the theory of these results, and promising, at the same time, that, if the result should fail, I should myself be the first to discredit my own system. I had the satisfaction to convince them that the result did fully answer my prediction and expectation. These experiments are the following, all made in a hot-house of the Botanical Garden in the winter of 1782.

I exposed to the sun-shine six globular glass vessels, each containing about 160 cubic inches of space, all filled with pump-water, which was boiled during more than two hours, and poured quite hot into the glass vessels, on purpose to prevent any access of air to the water.

Exp. I. In two of these vessels I put as much of the *conferva rivularis* (a water plant, classed by LINNÆUS amongst the *cryptogamia*) as was sufficient to take up the space of about an inch square.

Exp. II. In the two next vessels I suspended by threads tied to bits of cork, some pieces of woollen and silk cloth of different colours, as white, scarlet, green, and brown, having previously wetted them in some boiled water, on purpose to free them from all air.

Exp. III. In the two remaining vessels I placed nothing at all.

Exp. IV. In another vessel of the same form and size I put some of the *conferva rivularis*, and filled it with pump water.

All these globular vessels were inverted, with their orifices immersed in vessels filled with quicksilver, for the purpose of preventing effectually any communication between the contents of the vessels and the atmosphere.

*Result of experiment I.* The first two days neither of the vessels contained any air, and even the small quantity of air, which here and there adhered in the form of a bubble to the fibres of the vegetable when it was shut up in the vessel, had entirely disappeared. The third day, in the morning, some air bubbles began to rise from every part of the *conferva* in both glasses; and in the afternoon of the same day, a great quantity of air bubbles rose continually from it. I took at that time the vegetable out of one of these vessels. I plunged a wax taper, just extinguished, into the orifice of this vessel, on purpose to see whether the air, already extricated from the *conferva*, was dephlogisticated or not. The wax taper took flame immediately with an uncommon splendour. After this I poured the half of the water from the globular vessel into a common bottle, and corked it. I inverted this bottle afterwards

in an earthen vessel filled with boiled water. I placed this apparatus near the fire till the water in the bottle began to boil; after which I cooled the whole, and found a good quantity of air collected in the bottle, which air proved to be dephlogisticated. When I drew the vegetable out of the glass vessel I observed the water to sparkle almost like Seltzer water, or like water impregnated by art with fixed air. The vegetable which was still kept in the second bottle of exp. I. continued to yield air in the sun-shine, till it ceased to throw up any more air, towards the seventh or eighth day of its being shut up in the vessels. When, after this time, this globular vessel was shook, the water became full of small air bubbles, which for the most part rose to the inverted bottom of the vessel, great part of them settling upon the vegetable, which appeared all covered with them. This sparkling air, which became visible by shaking the glass, could not but be air originally produced by the *conferva*, and so loosely joined with the water, that it disengaged itself in a great measure from it by the motion of the vessel. After the tenth day the vegetable began to appear withered, grew yellow, and began to die. I found about eight cubic inches of dephlogisticated air collected in the vessel. This proved to be of a very eminent quality, its goodness being of  $352^{\circ}$ ; that is to say, that from a mixture of one measure of this air, and as many measures of nitrous air as were necessary to complete the full saturation, there were destroyed three measures and  $\frac{5}{8}$  of a measure, the test being made with Abbé FONTANA's Eudiometer, employed in the manner described in my book upon Vegetables, p. 278. *et seq.* The quality of this air was superior to that of any air I ever got from this plant in fresh pump water, its goodness proving, in general, to be from  $260$  to  $330^{\circ}$ , in the hot-house; this was during the winter, for I never had  
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been able to obtain such fine air from this vegetable in the summer\* ; the reason of which I will explain elsewhere.

*Theory of exp. I.* Boiled water, having lost its air, is very much disposed to imbibe it from all bodies which contain this fluid ; and therefore, during the first day or two of its exposure to the sun-shine with the vegetable, this water absorbed all the air which the plant emitted ; and even that which had remained entangled between the fibres of the vegetable when it was immersed in this water. The water being at last saturated with this air could take up no more ; and therefore, whatever air, after this saturation, came forth from the vegetable rose to the top of the vessel. The quantity of this dephlogisticated air was smaller than that which an equal bulk of the same plant commonly yields in fresh pump water, because a great deal of air was at first taken in or absorbed by the boiled water ; which absorption does not happen, or at least is not so great,

\* By continuing to make experiments, during the whole winter, in the hot-houses of the botanical garden, I found that the *conferva rivularis* yielded dephlogisticated air of a much superior quality to that I had ever been able to get from it in the summer, in the open air ; whereas those plants, such as the *agave Americana*, *cactus triangularis*, &c. which yielded in the summer the best air, did scarce yield any in the winter (and that of a quality scarce better than common air) though placed next to the *conferva*. The quantity of dephlogisticated air I got in the winter from the *conferva* was so great, that as much of this vegetable as occupies about the space of one cubic inch commonly yielded from 12 to 16 cubic inches of this air in the space of three or four days, when the sun did shine, the quantity of pump-water being about 160 cubic inches. The green matter which Dr. PRIESTLEY mentions as spontaneously produced from pump-water, gave in the winter also a tolerable quantity of dephlogisticated air, of a good quality, though not so fine, or in such large quantities, as it is used to give in the summer. It seems to be a general rule, that the greater the quantity of air obtained from vegetables in the sun is, the better is its degree of goodness.

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when pump water is used, as this water is always nearly saturated with air. The air, thus obtained in boiled water, was of a finer quality than that commonly obtained by the same means in pump water; because this air, being entirely free of air disengaged from fresh water, must of course be so much the purer dephlogisticated air. The water of the first vessel, and which was taken out of it as soon as air bubbles began to rise from the plant, sparkled like Seltzer water, and yielded by heat dephlogisticated air, because it was then already saturated with dephlogisticated air issuing from the vegetable. The water of this vessel being shook, after the vegetable ceased to throw up any more air in a visible way, still continued to sparkle; because, though the vegetable by losing gradually its vigour, was at last no more able to throw up air in visible bubbles, yet it had still enough of its vital power left to keep the water saturated with dephlogisticated air, so as to sparkle when shook. This vegetable, continually robbing the water of its natural air, found at last nothing more in it to support its life, and therefore at last languished and perished; which it did so much the sooner, from the contact of the dephlogisticated air, with which the water was impregnated, and to which the vegetable had been all that time exposed, having hurt its constitution (it is well known, that plants die in dephlogisticated air) and thus hastened its death. The sparkling quality of the water did not cease entirely till the vegetable was quite deprived of its life. The water began to sparkle every day very briskly, by being shook after the apparatus had been exposed an hour or two to the sun-shine, during the time the vegetable was in its full vigour, and ceased to do so some time after sun-set, or after the apparatus had been withdrawn from the sun's light; because this vegetable, like all others, elaborates no dephlogisticated air but by the influence

influence of the sun; and because this air, being but loosely united with the water, disengaged itself again from it, and rose to the inverted bottom of the vessel. The water being thus deprived of the dephlogisticated air, ceased to sparkle any more, till it became again saturated with it, after the apparatus had been exposed again, during some time, to the influence of the light.

*Result of exp. II.* No air at all was produced in the vessel containing the pieces of cloth, during three weeks exposure to the sun-shine.

*Theory of exp. II.* Boiled water, having lost its air, could yield none, at least till after a long time, when some degree of corruption took place in the animal substance, viz. the pieces of cloth.

*Result of exp. III.* Not an atom of air has appeared in this vessel, though it stood about two months upon the same place.

*Theory of exp. III.* Boiled water having no air, the sun could extricate none from it.

*Result of exp. IV.* the *conferva* began to yield air bubbles the very same day, a little while after its exposure to the sun. The next day it threw up an immense quantity of them. The fifth day it began to throw up less, and ceased entirely about the seventh day, when the quantity of about fourteen cubic inches of dephlogisticated air, of an excellent quality, though less fine than that obtained in exp. I. was collected. The water sparkled, as does Seltzer water, by the vessel being shook. This water being exposed to the fire, in an inverted vessel, yielded a good quantity of air, which was so far dephlogisticated as to be able to kindle a wax taper just extinguished. After the tenth day the vegetable began to die.

*Theory*

*Theory of exp. IV.* The vegetable threw up very soon air bubbles, because this water, being in its natural state, and thus saturated with air, could not absorb much of the air issuing from the vegetable, which air must, of course, soon rise up in visible bubbles. A great deal more air was collected than in exp. I. because less of the air issuing from the plant was absorbed by this water than in exp. I. The air obtained was not so good as that obtained in exp. I.; because the air in this experiment was somewhat infected by the air issuing from the water, which was but common air. The water sparkled when the vessel was shook, because this water, though it had probably lost some of its own air, yet had assumed a great deal of air from the plant \*, which air disengages itself from the water very easily, just as fixed air does; the more so when the water is moved.

\* It seems, that dephlogisticated air has by no means such a strong attraction to water, in other words, has not so much affinity with it, as common air has: it appears to be but loosely united with water, and quits it very easily by the water being shaken, or even though the water be kept quiet. May not this quality be looked upon as a providential one? for thus the dephlogisticated air, produced by water plants, is continually emitted by the water, and diffused through the common stock; and for this reason the water, when shook during the day-time, always sparkled as champagne; because at that time the water was always kept saturated by the dephlogisticated air, issuing continually out of the vegetable. But the water ceased to sparkle, after having been withdrawn from the sun-shine during some hours; because the dephlogisticated air, with which the water was saturated during the day-time (supposing the apparatus to be kept exposed to the sun) being but loosely united with the water, disengaged itself gradually from it, and rose to the top of the vessel. The sparkling quality of this water returned after the vessel had been exposed afresh to the sun; because the vegetable, resuming in that exposition its daily operation, communicated a fresh supply of dephlogisticated air to the water. This sparkling quality returned every day, as long as there remained any life in the vegetable; after which the water sparkled no more (though shook ever so much) either by day or in the night.

This water yielded, by heat, true dephlogisticated air; whereas the same water, when it has not been exposed to the action of a vegetable, yields by heat nothing but common air. The reason of it is, that the air elaborated by the plant, with which this water was saturated, was real dephlogisticated air. The vegetable at last languished and began to die, because the water was impregnated with dephlogisticated air, which being an excrement of the plant is hurtful to its constitution. Besides, this water had at last lost the most part of, or perhaps all, its own stock of common air; and with this all the nutritive nourishing and phlogistic particles, which were taken in by the plant, and was therefore become less fit to keep up vegetable life.

All these experiments were repeated frequently, and always with the same general results \*.

I think the abovementioned facts will be looked upon as quite sufficient to put my doctrine out of all farther question. I have many more facts, perhaps equally demonstrative with those just described; but, as this paper is already too long, I will keep them for some other opportunity. However, I cannot forbear making some farther remarks by which the point in question may be still farther illustrated.

If it was the water, and not the vegetable, which yielded the dephlogisticated air; and thus, if the reason why water plants and the green matter cease at last to throw up more air (if the

\* That air is thrown out of living vegetables exposed to the sun-shine, was already observed by the rev. Dr. Hales, as may be seen in vol. I. of his Statical Essays, p. 110. The apparatus which he used for this experiment is represented by fig. XVII. plate VII. But this inestimable philosopher, not even suspecting that this air was of a peculiar nature, did not collect it. BOYLE obtained much air from vegetables *in vacuo*.



water is not renewed) is, that the water being at last exhausted of its air can yield no more, it would necessarily follow, that the water, thus supposed to be deprived of air, should be similar to distilled or boiled water; but it is quite the reverse. This very water, instead of being exhausted of air, gives evident signs of being over saturated with it. It sparkles almost as champaign does, when shook by day-time in the sun; and it will, when it is at that time separated from the vegetable, yield by itself in the sun, but more so by the fire, a good quantity of dephlogisticated air. The reason why the green matter ceases at last to yield more air is therefore by no means because the water is exhausted of air; but, on the contrary, because it is too much saturated with it, and that with an air hurtful to vegetable life, and because this water has at last lost its own natural air, and together with this air the nourishing and phlogistic particles which are necessary to keep up the full vigour of plants.

If it was the water, and not the vegetable, which furnished the dephlogisticated air, why should the air bubbles not settle indifferently on either surface of the leaves? In this supposition, how could that admirable regularity be accounted for, by which all the leaves of a vine and a lime-tree are first covered with air bubbles on the under side, and all the leaves of *lauro-cerasus*, at the upper surface, whichever surface of the leaves is exposed to the rays of the sun? Why should the air always settle on most leaves in the form of bubbles, but never so upon the leaves of the *tropæolum majus*, at least during the first hours, but always in the form of bags, adhering to the upper edge of the leaves, and detaching themselves when they are grown to a certain size,

size, which never happens with leaves of a vine or lime-tree\*; whereas the green stalks of this plant (the *tropæolum majus*) are at the same time all covered with separate air bubbles? More of these remarkable appearances in different plants are to be seen in the third section of my book on Vegetables.

If the dephlogisticated air, obtained by means of vegetables in water, was air deposited from the water, and purified of its phlogiston, by remaining, during a certain time, in contact with the vegetable, it would follow, that this air would be so much the purer the longer it remains in contact with the vegetable; but it is quite the reverse. The air obtained from the leaves of a vine, to which the air bubbles stick a long while before they detach themselves and rise up, is never by far so much dephlogisticated as is the air obtained from some American plants, out of which the air rushes almost all in continual streams, as so many springs, not remaining a single moment upon the leaves. The difference of both airs is so great, that I never got dephlogisticated air from leaves of a vine, lime-tree, and such like, whose goodness surpassed  $260^{\circ}$  (it is commonly a little above  $200^{\circ}$ ); whereas I got commonly, from the above mentioned American plants, an air whose goodness was of above  $300^{\circ}$ , sometimes even of above  $350^{\circ}$ , in a very fair day, this air being put to the test, according to the manner which I have described before †.

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\* I have explained the reason of this singularity in that plant, in my book, where it is mentioned by the name of *naflurtium indicum*.

† The *sempervivum tectorum*, which grows almost every where upon the roofs of houses, gives also a very great quantity of dephlogisticated air of an eminent quality. It should seem, that all fleshy plants particularly excel in the quality of yielding fine dephlogisticated air, and a great quantity of it. The *agave Ame-*

If it was the water, and not the plant, which yielded the dephlogisticated air, the quantity of air obtained would bear, in general, a proportion to the quantity of the water employed; but this is by no means the case. The quantity of air bears a proportion to the bulk of the vegetable much more than to the quantity of the water. This is very easily to be observed with some of the above mentioned American plants. It ought to be always observed, that if too many leaves are crowded together, they shade one another too much; and therefore, in this case, the quantity of air obtained will be proportionably less, and its quality worse.

Again: if the dephlogisticated air, obtained from plants in water, was air disengaged from the water, it would follow, that a plant shut up in a transparent glass vessel without any water would yield no air at all, nor increase the quantity of air shut up with the vegetable. The following experiment, I think, will be sufficient to convince any one that this is far from being the case. I placed in a glass tube, hermetically sealed at one end, a piece of an American plant, called *cereus*; the extremity of this piece, where it was cut from the plant, was tightly squeezed in a small glass vessel, in which only as much water was kept as seemed to be required to keep the *cereus* in full vigour. I smeared the vegetable, and the orifice of the glass vessel all around with soft wax, so that all communication between the air within the tube and the water within the small vessel was cut off. I placed this tube inverted in a vessel filled with quicksilver, keeping a column of some inches of

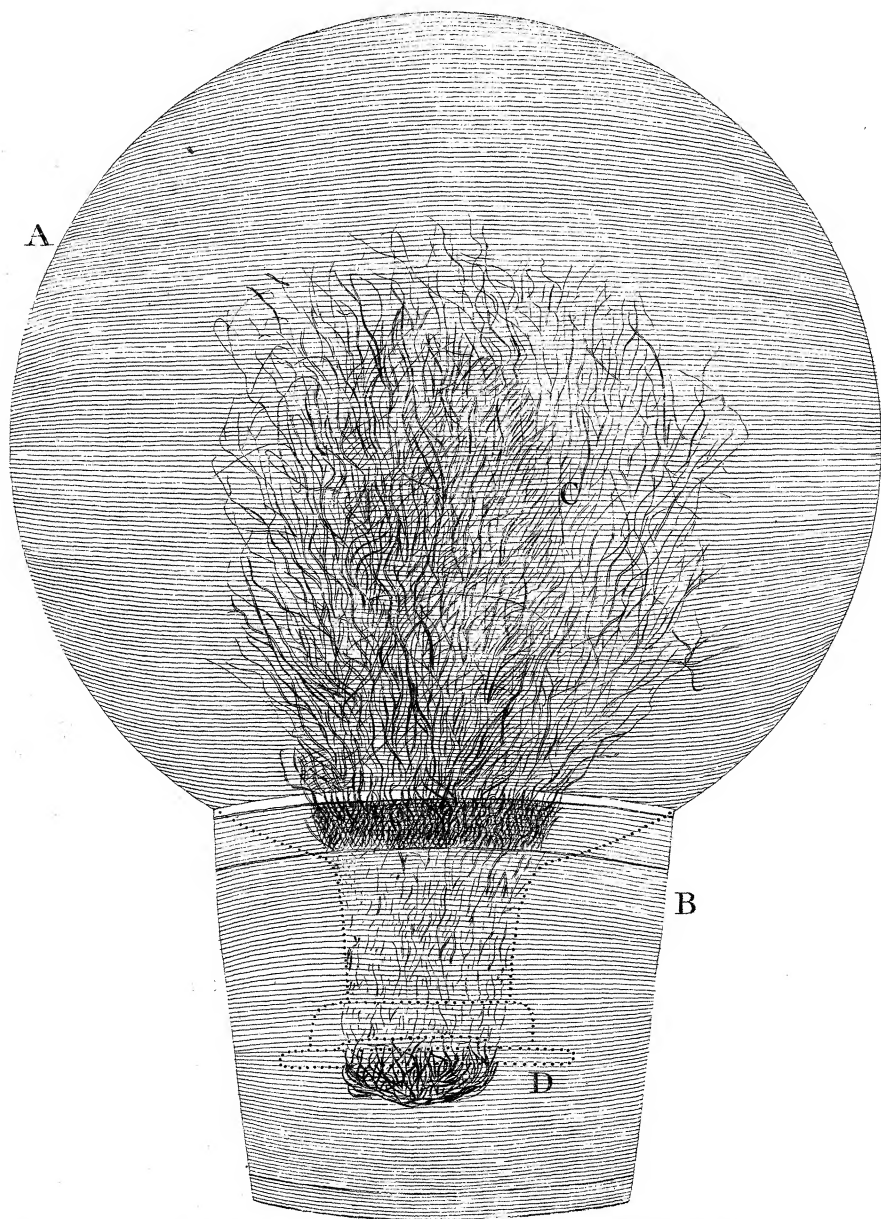
*ricana* gives such a prodigious quantity of dephlogisticated air, that, in a fair day, I often got from one single leaf above 150 cubic inches of this air, of the finest quality. The *cactus triangularis*, *cereus*, *sempervivum arborum*, and many others give no less air.

the metallic fluid in the tube, to allow the air within the tube to expand by the heat of the sun without escaping. After this apparatus had stood during a few hours, in a bright sun-shine, I cooled the whole to the same degree it possessed when it was exposed to the sun. This was done by plunging the whole in a tub filled with water, whose degree of heat was restored to the same degree it had before. I found the quantity of air within the tube remarkably increased, and so far dephlogistified that a flame burned in it with an increased brightness, and that one measure of it joined to one measure of nitrous air occupied 0.64; whereas the same air, before it was shut up with the *cereus* was of such a degree of goodness, that one measure of it with one of nitrous occupied 1.06. Though this experiment may fully shew that plants throw out air in the sun-shine, yet if another plant, which does not by nature yield so much air as the *cereus* commonly does, is shut up in a similar tube, and exposed to the sun, the same effect will not always be obtained. The reason of it is, that plants absorb a good quantity of common air as their nourishment at the same time that they throw out dephlogistified air. This fact, therefore, if considered by itself, will not be looked upon as equally demonstrative with the above mentioned ones. The result of this experiment may depend on the more or less vigour of the vegetable employed, on the more or less brightness of the sun's light, on the more or less heat the vegetable receives, &c. A *cereus* being a plant of hot climates may bear more heat than an European plant. All these circumstances, as well as many others, may make the issue of this experiment sometimes ambiguous; but the fact, as I have related it, joined to the above mentioned analogous experiments  
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of Dr. HALES and Mr. BOYLE, will add strength to my assertion, viz. that vegetables really throw out air in the sun-shine.

If all what I have said hitherto should not be thought sufficient to take away the prejudice which Dr. PRIESTLEY's fifth volume, and Mr. CAVALLO's book on Air, may have produced in the mind of some philosophers, I should advise them to be present, at least once, at the most beautiful scene which they will behold, when a leaf of an *agave Americana*, cut in two or three pieces, is immersed in a glass bell or jar full of pump-water, inverted and exposed to the sun in a very fair day in the middle of the summer, when this plant is in its full vigour; and when they shall have seen those beautiful and continual streams of air, which rush from several parts of this vegetable, principally from the white internal substance of it, I will be answerable for their laying aside all farther doubt about the truth of my doctrine.

After having now demonstrated, as I think, in the clearest manner, that vegetables diffuse through our atmosphere, in the sun-shine, a continual shower of this beneficial, this truly vital air; and that plants immersed in water, far from robbing it of all air, impregnate it fully with a better and more salubrious air; let us not pass so wonderful, and hitherto not even so much as suspected, an operation of nature, without admiring the designs of that infinite wisdom, who has employed such hidden, such wonderful, and at the same time such beneficial means to preserve from destruction the living beings which inhabit our earth; and let us consider, whether it would not be worth while to attempt drawing some benefit from this new discovery, by making use of vessels of water, in which some leaves of vegetables have been exposed in the sun-shine; by placing such vessels in our rooms; by stirring the water; by  
sprinkling



- A. a globular glass vessel containing about 160 cubic inches of water.  
B. glass vessel fill'd with Mercury in which the orifice of the spherical vessel is plunged.  
C. a vegetable called *Conferva rivularis*.  
D. a piece of wood to which the *Conferva rivularis* is attached to keep it in its place.

sprinkling with it our floors instead of using for this purpose common water; by placing within our houses, instead of flower-pots, dishes containing some *conserva rivularis*, a plant to be met with almost every where, shooting forth with the utmost luxuriance in all water basons, in all tubs and vessels in which water is kept. Is it possible, after all this, not to believe, that the Creator has multiplied this vegetable with a similar view to our benefit? This benefit we may now, with some confidence, apply to our preservation, by honouring this vegetable with a place in those of our own rooms which are exposed to the sun, and keeping it alive as long as we please; which may be done by only pouring every day fresh water upon it, and squeezing gently now and then out of it the dephlogisticated air with which the whole mass swells up almost as soon as the sun casts its rays upon it. The water itself, in which it has been immersed, will now, perhaps, be looked upon as too precious to be thrown away as useless and deprived of that very principal of animal life, of which I have demonstrated it to be highly pregnant.

